Fog- and cloud-induced aerosol modification observed by the Aerosol Robotic Network (AERONET)

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Large fine mode (sub-micron radius) dominated aerosols in size distributions retrieved from AERONET have been observed after fog or low-altitude cloud dissipation events. These column-integrated size distributions have been obtained in many regions of the world, typically after evaporation of low altitude cloud such as stratocumulus or fog. Retrievals with cloud processed aerosol are sometimes bimodal in the accumulation mode with the larger size mode often ~0.4 – 0.5 μm radius (volume distribution); the smaller mode typically ~0.12 to ~0.20 μm may be interstitial aerosol that were not modified by incorporation in droplets and/or aerosol that are less hygroscopic in nature.

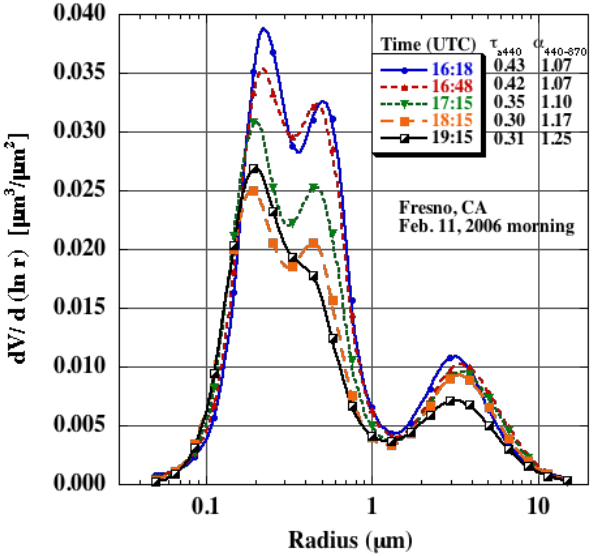

Figure 1. Almucantar size distribution retrievals from Fresno, CA on the morning of 11 February 2006 over a time interval of 3 h for these five almucantar scans.

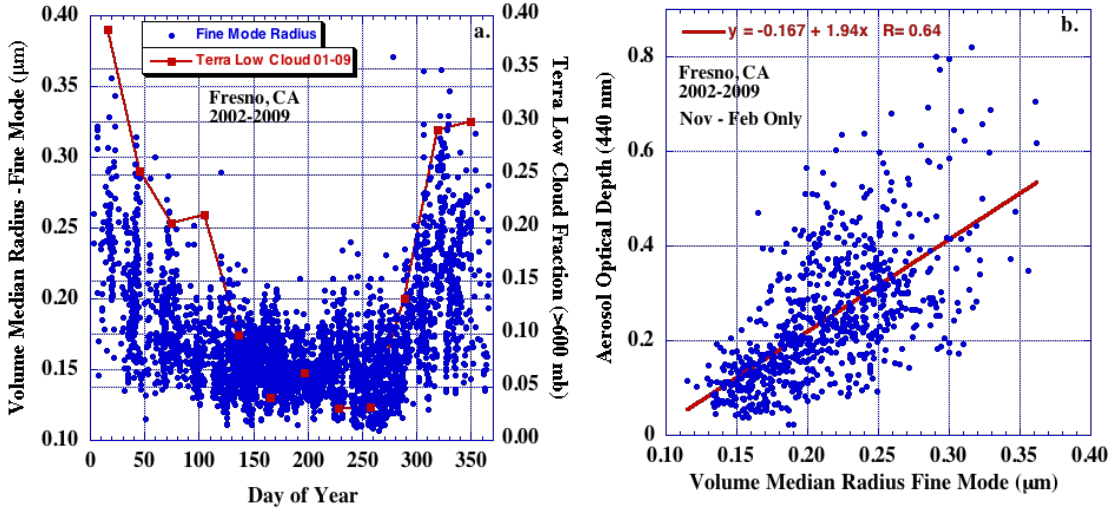

Figure 2. (a) All of the AERONET retrievals of fine mode radius made at Fresno versus day of the year for the time interval of 2002–2009. Also shown is the monthly mean low cloud fraction from Terra MODIS (cloud top >600 mb) averaged over the 2001 through 2009 interval. (b) Relationship between fine mode radius and aerosol optical depth at 440 nm at Fresno is shown for retrievals made during the months of November through February only.

Observed trends of increasing aerosol optical depth (AOD) as fine mode radius increased suggests higher AOD in the near cloud environment and therefore greater aerosol direct radiative forcing than typically obtained from remote sensing, due to bias towards sampling at low cloud fraction.

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References:

Eck, T. F., et al. (2012), **Fog- and cloud-induced aerosol modification observed by the Aerosol Robotic Network (AERONET)**, *J. Geophys. Res.*, *117*, D07206, doi:10.1029/2011JD016839.

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Data Sources: The measurements we have analyzed were made by sun-sky radiometers that are a part of NASA's AErosol RObotic NETwork (AERONET; Holben et al., 1998)), which is a federated global network of standardized radiometers calibrated to consistent reference sources and processed with state of the art algorithms. Over 400 sites located in diverse environments on all continents and oceanic islands are currently a part of AERONET.

The AERONET sites in Kanpur (Indo-Gangetic Plain, northern India), Arica (Chile; Pacific coast adjacent to large stratocumuls field) and Fresno (California, San Joaquin Valley) are all in regions that experience seasonal low altitude clouds or fog. Monitoring of aerosol optical properties at these sites has been accomplished for multiple years and from 6-8 years of data were analyzed at each site investigate to the interaction between fog and/or low altitude clouds and aerosols (Eck et al., 2012). In addition to in depth studies at these sites, AERONET data at other sites were also analyzed, including the GSFC site.

Technical Description of Figures:

Figure 1: Almucantar size distribution retrievals from Fresno, CA on the morning of 11 February 2006 over a time interval of 3 h for these almucantar scans. The larger of the sub-micron modes (likely cloud processed) shows a peak radius decreasing from ~0.50 to ~0.45 μm, while the smaller mode also remained relatively constant at ~0.22 to ~0.19 μm (the slight decrease of the smaller mode may be related to decreasing RH) over the time interval of ~3 hrs.

Figure 2: (a) All of the individual AERONET retrievals of fine mode radius made at Fresno versus day of the year for the time interval of 2002–2009. Also shown is the monthly mean low cloud fraction from Terra MODIS (cloud top >600 mb) averaged over the 2001 through 2009 interval. The coinciding occurrence of larger fine mode radius values with higher cloud fraction of low altitude clouds from November through February is consistent with the possibility of fog/cloud processing and/or interaction. (b) Relationship between fine mode radius and aerosol optical depth at 440 nm at Fresno is shown for retrievals made during the months of November through February only. There is a significant trend of increasing AOD as fine mode radius increases ($r = 0.64$), which likely results partly from greater scattering efficiency as particle radius increases, in addition to possibly higher aerosol number concentrations being correlated with larger radius particles.

Scientific significance: Aerosol interactions with clouds are currently the largest source of uncertainty in assessment of the anthropogenic aerosol radiative forcing on climate [Intergovernmental Panel on Climate Change (IPCC), 2007]. This pertains primarily to how aerosols modify cloud properties such as albedo and lifetime, and for absorbing aerosol particles the semi-direct effect of suppression of convection. However, the related modification of aerosol properties by interaction with clouds is also of significant importance in accurately assessing aerosol evolution and direct radiative forcing. This paper presents an investigation of aerosol processing by clouds or fog, from analysis of AERONET remote sensing retrievals.

Relevance for future science and relationship to Decadal Survey: The interaction of aerosols and clouds and resultant effects on aerosol optical depth and size distribution currently contribute to significant uncertainties in radiative forcing of aerosols at the earth's surface and the top of the atmosphere. AERONET measurements of AOD and retrieval of aerosol optical and physical properties such as size distributions have and will continue to be utilized in climate forcing studies and in the validation of current and future satellite missions.